DE LA RECHERCHE À L'INDUSTRIE

Test plan (SAR2) and acceptance criteria

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Outline

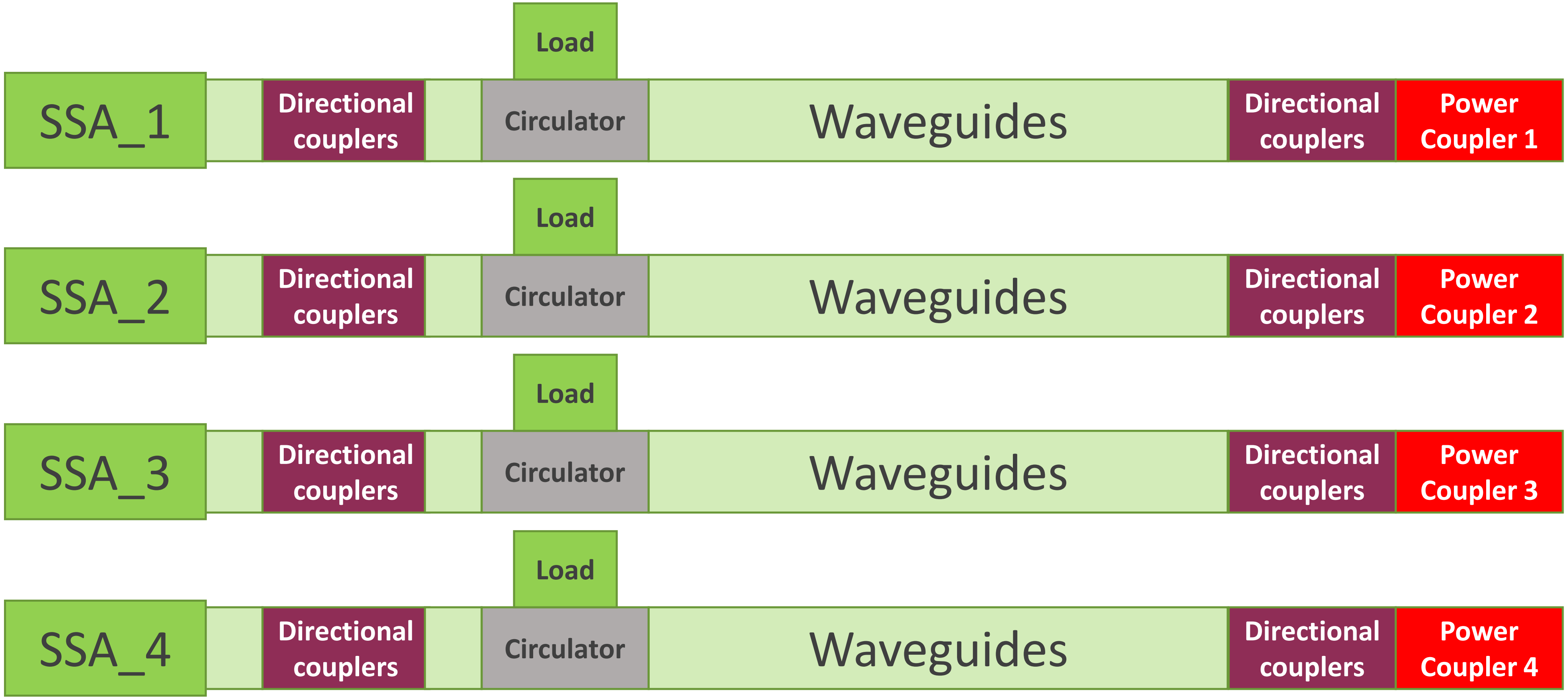
- **Current situation**
- **Test Facility :**
  - RF power configuration
  - Test Bunker
- **Preliminary Acceptance Criteria List (ACL)**
- **Preliminary Test Plan**

Current situation

- CEA initial choices for RF power equipment and configuration were made in agreement with Fermilab.
- The Acceptance Criteria List (ACL) and the test plan of the LB650 cryomodule are currently under discussion between CEA and Fermilab. A preliminary version is presented here.
- The HB650 cryomodules ACL and test plan will be the baseline for the LB650 cryomodules.
- The HB650 prototype cryomodule test will be performed at Fermilab more than one year prior to the first test of the LB650 cryomodule at CEA. This experience feedback will be very valuable for the LB650 cryomodule test activities.

RF power test configuration

- Four independent 650 MHz Solid State RF Amplifiers (SSA) to allow independent cavity tests
- Circulators to allow operation with CW full reflection configuration
- RF generator coupled to a PLL for each SSA to track each cavity frequency
- Directional coupler positioned near the power coupler to have accurate RF power measurements



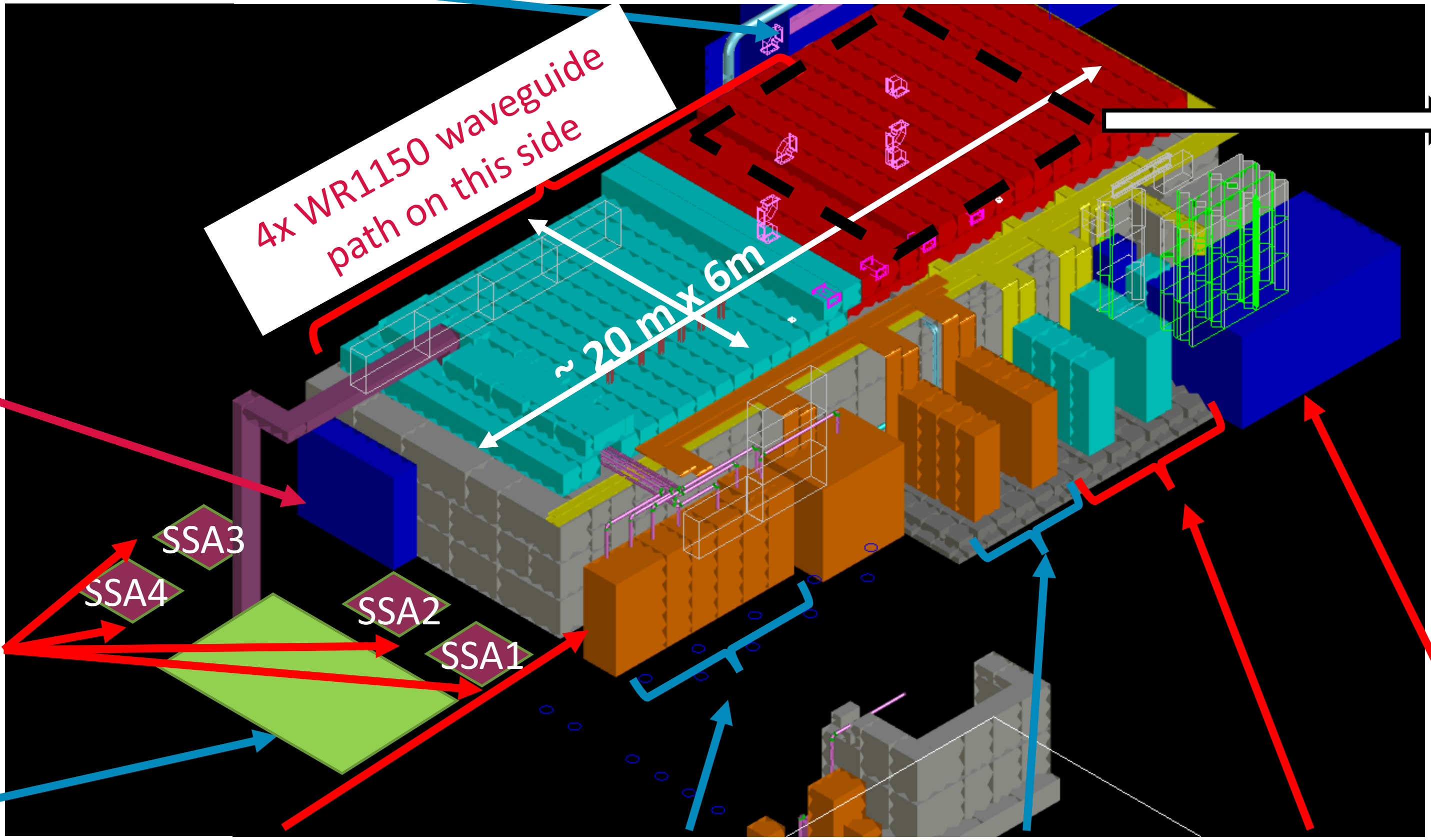
LB650 cryomodule test bunker

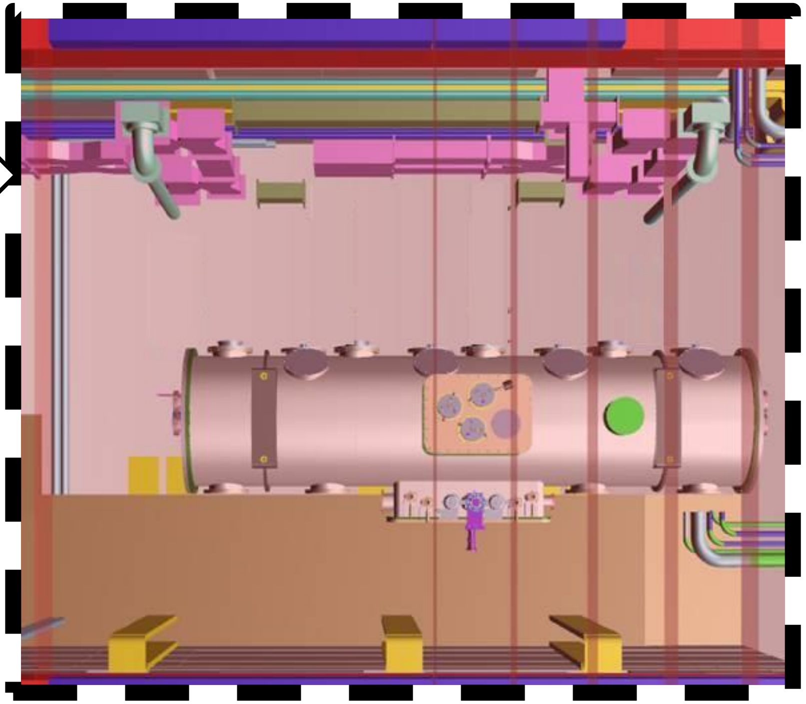
- The PIP-II LB650 cryomodule cryogenic and RF test will take place in the bunker used currently for both ESS and SARAF projects. **In red what will be potentially used by PIP-II.**

Current ESS 704 MHz WG path

Electrical power

Future ~ 19kW 650MHz SSA positions





PIP-II LB650 Cryomodule

SARAF control room

Demineralized water supply here

SARAF 176MHz SSAs and RF power equipment

SARAF Racks

ESS Racks **(This zone can be used for PIP-II racks)**

ESS Control room **(Potentially to be used by PIP-II)**

Preliminary Acceptance Criteria List (1)

Values in the Acceptance Criteria LIST are based on data form the PIP-II LB650 Cryomodule TRS document ED0009658, Rev. A and the Preliminary HB650 Cryomodule ACL

	Criteria	Design Validation
1	Cavity beamline vacuum a.) Cold (2K) ≤ $1x10^{-8}$ Pa; after cryomodule thermal equilibrium reached at 2K, beamline isolated. b.) Warm (RT) ≤ $1x10^{-5}$ Pa; after 72 hours of pumping.	Beamline vacuum pumping and leak tightness.
2	Insulating vacuum a.) Cold (2K) ≤ $5x10^{-5}$ Pa after cryomodule thermal equilibrium reached at 2K b.) Warm (RT) ≤ $5x10^{-3}$ Pa	Vacuum pumping and leak tightness of the vacuum vessel
3	Center Frequency = 650.000 MHz +/- 10kHz for all cavities @ 2K	Cavity fabrication and tuner pre-load target frequency
4	Individual cavities reach 16.9 MV/m + 15% overhead	Overall cavity design, processing, and assembly.
5	Field emission onset ≥ 11.9 MV/m for each cavity (final criteria will be set after the prototype HB650 Cryomodule test)	Cavity processing, HPR effectiveness and clean assembly techniques
6	Field Emission: radiation dose rate ≤ 0.5 mSv/hr when cavity is operated at its max operating gradient (16.9 MV/m + 15% = 19.5 MV/m), as measured by FOXes situated 2m from cavity centerline	Cavity processing, HPR effectiveness, and clean assembly techniques

Preliminary Acceptance Criteria List (2)

	Criteria	Design Validation
7	Each cavity $Q_0 \geq 2.4 \times 10^{10}$ at 16.9 MV/m	Cavity performance and verification of 2K dynamic heat load
8	Slow Tuner range ≥ 200kHz measured at 2K Stepper motor resolution < 2Hz/step Slow Tuner hysteresis ≤ 100 Hz	Tuner design and assembly
9	Fast (piezo) Tuner range ≥ 1200 Hz measured at 2K Fast Tuner resolution < 0.5 Hz, measured at 2K	Tuner design and assembly
10	Cold cavity alignment error.	Alignment strategy, strongback design and accuracy
11	Nominal FPC Q_{ext} (measured at 2K at low power (Network Analyzer)) = 1.04×10^7 with range ± 20%	FPC design verification
12	Power coupler intercept temperatures during steady-state operation, cryogenic equilibrium reached: 5K intercept ≤ 15K 50K intercept ≤ 125K	FPC/CM thermal design verification
13	Measure total heat load on the CM with all cavities operating at 16.9 MV/m : Dynamic and static heat load for 2K, 5K and 50K following data in the ED0008200 reference document	Global thermal design verification

Preliminary Test Plan (1)

- Warm Pre-Test Checkout
  - Instrumentation, signal integrity, vacuums, cavity & tuner, alignment
  - RF power Source+ LLRF, Interlock system, coupler HV bias and air cooling system
- Beamline and isolation vacuum measurements
- Warm power coupler RF conditioning (Not yet decided)
- Cooldown to 4K: Thermal shield cooldown then fast cooldown with verification of the magnetic flux expulsion
- Cooldown to 2K with measurements of the cavity frequency and monitoring of Df/DP
- Prepare for 2K testing: Cryogenic instrumentation (data-logged throughout)
- Power coupler RF conditioning (off resonance)
- Measure cavity frequencies, power couplers Qext, exercise tuner fast and slow, cavity pre-tune to center frequency

Preliminary Test Plan (2)

- Thermal stability reached: RF cable/system calibration, beamline and isolation vacuum measurement, alignment measurement
- Radiation detector operational and data logged
- Individual Cavity RF Testing @ 2K using PLL : FE onset, process MP & FE, determine field limit (quench, or admin), LFD coefficient.
- Tuner performance (slow and fast): range, resolution and hysteresis
- 2K heat load (Q_0) measurements
- Static heat load measurements (CM has been cold for ~2 weeks): for each circuit 50K, 5K and 2K.
- Ensemble cavity tests: all the cavities at maximum nominal gradients
  - Total 2K dynamic heat load measurements
  - Stability test (several hours until power coupler thermal equilibrium achieved)

Conclusion

- The LB650 cryomodule test will take benefit form the test facilities currently used for ESS and SARAF.
- The main choices for the RF power equipment are agreed with Fermilab.
- The ACL and test plan of the HB650 cryomodule are used as baseline for the LB650 cryomodule tests.
- Discussion between CEA and Fermilab about ACL and test plan of the LB650 cryomodule is in progress. Preliminary versions are presented here.
- The HB650 prototype cryomodule test will provide a import experience feedback for the LB650 cryomodule tests to be performed at CEA.

Thank you for your attention